Aspects of the population dynamics of *Liza klunzingeri* in the Kuwait Bay

by

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ABSTRACT. - The growth characteristics of *Liza klunzingeri* (Day, 1888) in Kuwait Bay were evaluated based on data collected from 1982 to 1999. Length-based stock assessment showed an asymptotic length (L_∞) of 24.8 cm TL and growth curvature (K) of 0.46 yr^{-1}. The growth of *L. klunzingeri* follows the seasonally oscillating VBGF typical of temperate species with both an amplitude (C) and winter point (WP) of 0.95. The total mortality coefficient (Z) was estimated to be 4.61 yr^{-1} for raw data and 4.27 yr^{-1} after accounting for gear selection. Logistic selection model showed that 25% of fish of 3.5 cm TL, 50% of specimens reaching 4.8 cm TL and 75% of all specimens of 6.1 cm TL encountering the gear are retained. From the raw data, two recruitment peaks in a year seem to be evident, a minor one in May (13.5%) and a major one in September (17.5%). However, after accounting for gear selection, the recruitment strength was confined to September (37.8%). The current exploitation rate of 0.75 is above the optimum (0.239), the maximum (0.373) and the economic (0.305) yield indices. It is estimated that the Maximum Economic Yield (MEY) would be obtained when the average weight of fish caught is 0.6 of the maximum weight or 60% of the asymptotic weight. The traps used in the fishery seem to have adverse effects on recruitment and could be the cause of depression in the stocks. Management implications are discussed in the light of growth, mortality, recruitment and exploitation of *Liza klunzingeri* in the Kuwait Bay.

RÉSUMÉ. - Aspects de la dynamique de population de *Liza klunzingeri* dans la baie du Koweït.

La croissance individuelle de *Liza klunzingeri* (Day, 1888) a été étudiée dans les eaux koweitiennes à l'aide de données collectées de 1982 à 1999. L'examen des distributions de fréquences de tailles conduit aux valeurs suivantes : L_∞ = 24,8 cm TL et coefficient de croissance K = 0,46 an^{-1}. La croissance de *L. klunzingeri* subit des variations saisonnières d'amplitude élevée avec un minimum en fin d'année ; WP = 0,95. La mortalité totale (Z) est de 4,61 an^{-1} sans tenir compte de la sélectivité des engins et de 4,27 an^{-1} en incorporant celle-ci. En effet, on peut estimer que 25% des poissons de 3,5 cm TL, 50% de ceux de 4,8 cm TL et 75% de ceux de 6,1 cm TL sont retenus par les filets. Le recrutement a lieu en deux phases : l'une en mai (13,5%) et l'autre, plus importante, en septembre (17,5%). Si l'on tient compte de la sélectivité, un seul mode de recrutement survient en septembre (37,8%). Le taux d'exploitation actuel est de 0,753, très au-dessus du taux optimal (0,239), maximal (0,373) et économique (0,305). Ceci indique une surexploitation de *Liza klunzingeri* dans les eaux de la baie du Koweït. Le "Maximum Economic Yield" (MEY) pourrait être atteint si les poissons capturés pesaient 60% du poids asymptotique actuel. Les nasses employées actuellement semblent avoir des effets néfastes sur le recrutement et être à l'origine de la diminution du stock. Les implications en matière d'aménagement sont discutées en termes de croissance, de mortalité, de recrutement et d'exploitation de *Liza klunzingeri* au Koweït.

Key words. - Mugilidae - *Liza klunzingeri* - Kuwait Bay - Growth - Recruitments - Mortality - Gear selectivity - Yield indices.

The Arabian Gulf is considered one of the richest areas in fishery resources where large quantities of fish and shrimps are concentrated in different locations, particularly in the territorial waters of the State of Kuwait (Al-Omaim, 1995). The multispecies fishery in this region is dominated by many commercially important species including *Liza klunzingeri*, *Pampus argenteus*, *Acanthopagrus* spp., *Epinephelus tauvina, Formio niger, Tenualosa ilisha, Pomadasys kaanan, Otolithes argenteus, O. ruber* (Al-Husaini *et al*., 2001; Al-Husaini, 2002; Bishop, 2002, 2003). Despite their commercial importance, it is only recently that some of the species have been a subject of biological investigations: reproduction (Abou-Seedo and Al-Khatib, 1995; Dadzie *et al*., 1998, 2000a; Abou-Seedo *et al*., 2003; Abou-Seedo and Dadzie, 2004), community structure and fish assemblages (Abou-Seedo, 1992; Wright *et al*., 1996), food and feeding habits (Dadzie *et al*., 2000b), length-weight relationships (Dadzie *et al*., 2000c; Abou-Seedo *et al*., 2002). From the above, the only studies by Abou-Seedo and Al-Khatib (1995) and by Abou-Seedo and Dadzie (2004) targetted specifically *L. klunzingeri*. The only pioneering reports concerning population dynamics (Morgan, 1981, 1982, 1985; Ali and Mahmood, 1993; Al-Husaini *et al*., 2001; Al-Husaini, 2002) ignored *L. klunzingeri*. Meanwhile, the fishing industry of Kuwait continues to exploit the fishery resources of its territorial waters with great intensity. This has already led to the depletion of some of the valuable species. For example, the catches of *Pampus argenteus* have declined from 1,100 tonnes in 1994 to 120 tonnes in 2000. Similarly, the catches by the Iranian fleet have decreased substantially from 1,142 tonnes in 1996 to only 114 tonnes in 2000 (Al-Husaini, 2002). It is believed that the *P. argenteus* stock in the Northern Gulf is subjected

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to recruitment-overfishing as well as size-overfishing, and that the tuna and mackerel are even more vulnerable to overfishing (Bishop, 2002). This calls for baseline research data on the other commercially-important species, such as *L. klunzingeri*, on which there is scarcity of information both locally and regionally, for their management and rational exploitation.

It was against this background of information scarcity on the biology of *L. klunzingeri*, coupled with the need to provide much-needed scientific data for the management and rational exploitation of this valuable resource, that the present study was undertaken to evaluate the growth characteristics of this species in the Kuwaiti waters, using FiSAT II and LFSA packages on size composite data from 1982 to 1999.

MATERIALS AND METHODS

The fish samples used in this study were captured from the Kuwait Bay (Fig. 1), using stake traps, locally known as *hadra* (Abou-Seedo, 1992). Total lengths of all fish caught were recorded to the nearest 0.1 cm. The length measurements were grouped into 1 cm-length classes for the construction of monthly length distribution from 1982 to 1999. The annual size-frequency data was merged to create one annual composite data set for the year 2000, to take care of low sample sizes.

The data were entered into a computer using the FAO-ICLARM Stock Assessment Tools II (FiSAT II) (Gayanilo and Pauly, 1997). Direct fit of length-frequency data was carried out using the ELEFAN I routine of the package. Response surface analysis was first used to determine which of the several growth curves gives the best 10 score. These

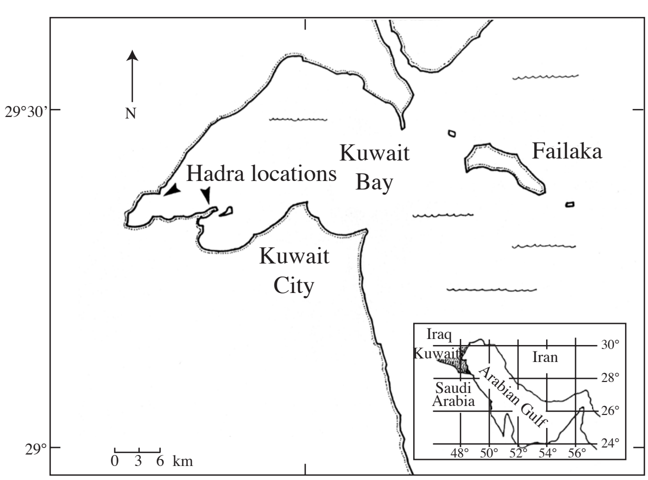

Figure 1. - Map of Kuwait Bay, showing the sampling locality of *Liza klunzingeri*. *[Carte de la baie du Koweit indiquant la localité de capture de* Liza klunzingeri.*]*

values were highlighted to aid in selection of the best set of data. The K-scan was then used to assess the reliability of the K estimate.

The best growth curve was then fitted by defining the best sets of asymptotic length (L_∞), growth curvature (K), amplitude of seasonalized growth (C) and the winter point (WP), which is the period of the year with the slowest growth (winter point set to 15th December). An oscillating growth curve of the following form was used:

$L_t = L_\infty (1 - Exp(-K(t - to) + St_s + St_o))$

where: $St_s = (CK/2\pi) \cdot \sin (2\pi(t-t_s))$; $St_o = (CK/2\pi) \cdot \sin (2\pi(t_o-t_s))$, and L_t is the length at time t.

Growth performance index (φ')

According to Pauly and Munro (1984), the growth performance index was computed from the relationship:

$\varphi' = \text{Log } K + 2\text{Log } L_\infty$

Length-converted catch-curve

The seasonalized catch-curve applied to the summed length-frequencies was of the form: $\ln(N) = a + b \cdot t'$, where N is the number of fish in a given length-class, obtained as a pseudo-cohorts by "slicing" away the polynomial frequency distribution using successive growth curves, t' is the relative age of the fish in that pseudo-cohort, while b, with sign changed, provides an estimate of Z (Pauly, 1984, 1990).

Following the estimation of Z, the routine was also used to estimate the natural mortality coefficient (M) according to Pauly (1980), and the fishing mortality coefficient (F), from Z = M + F as well as the exploitation ratio, E = F/Z, where E is the exploitation rate.

Mortality (M)

Pauly's equation (Pauly, 1980) has the following form:

$\ln(M) = -0.0152 - 0.279\ln(L_\infty) + 0.6453\ln(K) + 0.463\ln(t)$

where, L_∞ = is the approximate total length (cm), K = the annual growth, and t = the mean annual habitat temperature (°C).

Probabilities of capture

Catch curve analysis was then extended to an estimation of probabilities of capture by backward projection of the number that would be expected if no selectivity had taken place (N'), using:

$N_{i-1}' = N'_i \cdot e^{(Z\Delta t)}$

with Δt being the time needed for the fish to grow through length class i;

$Z = (Z_i + Z_{i+1})/2$; $Z_i = M + F_i$; $F_{i-1} = F_i - X$ and $X = F/$(number of classes below P_i +1);

and where P_i is the first length-group with a probability of capture equal to 1.0, and whose lower limit is an estimate of L'. From this, probabilities of capture by length were computed from the ratios of N_i/N'_i.

Table I. - Monthly composite length-frequency data of *Liza klunzingeri* representing samples collected from 1982 to 1999 pooled together. *[Longueur et fréquence mensuelles de* Liza klunzingeri *à partir d'échantillons collectés de 1982 à 1999.]*

Length-class TL (cm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1-2	0	0	0	0	0	0	0	0	0	0	0	0
2-3	109	9	0	59	8	26	4	0	0	0	9	0
3-4	301	125	0	168	149	48	17	0	0	0	20	1
4-5	11	5	0	31	141	18	3	0	0	0	0	0
5-6	0	1	0	34	40	5	2	0	19	0	0	0
6-7	0	1	0	5	3	17	40	0	1	0	0	4
7-8	0	1	0	1	1	6	19	0	0	0	3	8
8-9	0	0	0	1	0	1	1	0	0	0	0	5
9-10	0	0	0	0	0	0	0	0	0	0	7	1
10-11	2	0	0	1	0	0	1	0	2	2	22	3
11-12	2	1	7	3	3	0	1	5	13	23	48	30
12-13	3	1	97	84	85	17	45	37	58	64	119	101
13-14	4	9	169	221	411	116	111	62	131	70	85	29
14-15	29	17	95	112	276	124	100	125	141	112	60	3
15-16	25	29	125	71	97	76	63	91	102	107	60	16
16-17	29	33	67	34	39	42	31	25	37	41	43	32
17-18	13	18	29	3	8	17	4	6	11	7	18	8
18-19	5	6	3	0	0	5	0	1	1	2	11	1
19-20	0	0	0	0	0	2	0	0	0	0	2	0
20-21	0	0	1	0	0	1	0	0	0	0	2	0
Total	533	256	593	828	1261	521	442	352	516	428	509	242

The probabilities of capture were then used to correct the monthly samples for selectivity for re-analysis of growth parameters and mortality estimates.

Recruitment pattern

Growth parameters L_∞, K, C and WP were used as inputs, by backward projection, along a trajectory defined by the VBGF, of the frequencies onto the time axis of a time-series of samples. In this way, plots showing the seasonal patterns of recruitment were obtained.

Beverton and Holt Y/R and B/R analyses

The relative yield-per-recruit model used was based on the Beverton and Holt (1966) model, modified by Pauly and Soriano (1986). The options assuming knife-edge selection was utilized, using probabilities of capture. L_c/L_∞ and M/K ratios were used as inputs.

Relative yield-per-recruit (Y'/R) was computed from:

$$Y/R' = EU^{M/K}\left\{1 - \frac{3U}{(1+m)} - \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)}\right\}$$

where: $U = 1-(L_c/L_\infty)$; $m = (1-E)/(M/K) = (K/Z)$; $E = F/Z$

Relative biomass-per-recruit (B'/R) was estimated from the relationship:

B'/R = (Y'/R)/F, while

E_{max}, $E_{0.1}$ and $E_{0.5}$ were estimated by using the first derivative of this function. E_{max} is the exploitation rate at Maximum Sustainable Yield (MSY), $E_{0.1}$ is the rate at Maximum Economic Yield (MEY) and $E_{0.5}$ is the optimum exploitation rate.

RESULTS

Growth parameters

The samples for each month from 1982 to 1999, combined to form a composite sample for this study, are presented in table I. Combining the samples enabled us to meet the requirements for length-based methods.

The K-scan technique indicated an L_∞ of 24.8 and a K value of 0.46 (Fig. 2), while surface response analysis gave an L_∞ of 24.8 and a K value of 0.50 for the original data set. These results gave a growth performance (f') of about 2.45 for *L. klunzingeri* in the Kuwait Bay, with the corresponding f' values for different combinations of L_∞ and K. For growth analysis, a winter point of 0.95 was used which corresponds to 15th December (winter) when growth is expected to be minimal. An amplitude of 0.95 was also used to seasonalize the von Bertalanffy growth curve. The seasonalized von Bertalanffy growth curve resulting from a combination of 24.8 cm asymptotic length and growth curvature of 0.46 is shown in figure 3.

Mortality estimates, relative yield per recruit and average biomass per recruit

The total mortality coefficient from length-converted catch curve indicates an annual estimate of 4.61 yr^{-1} with a confidence interval from 3.22 to 6.00 yr^{-1}, but after correcting for gear selectivity, the re-calculated total mortality coefficient was 4.27 yr^{-1} with confidence interval from 3.18 to 5.38 yr^{-1} (Fig. 4).

The Beverton and Holt relative yield per recruit model (Fig. 5) showed that the indices for sustainable yields are 0.239 for optimum sustainable yield ($E_{0.5}$), 0.373 for the maximum sustainable yield (E_{max}) and 0.305 for economic yield target ($E_{0.1}$). From the analysis of mortality rates, the current exploitation rate was estimated as 0.753, which is already above the maximum, optimum and economic yield indices.

Gear selectivity

The typical selectivity for *L. klunzingeri* caught in the hadra nets shows that at least 25% of fish of 3.5 cm TL are retained by the traps while 50% of the fish of 4.8 cm TL are retained on encounter with the gear. The logistic selection model also shows that at least 75% of all fish of 6.1 cm TL are retained by the traps (Fig. 6). All fish above 13 cm TL are retained in the traps.

Recruitment

Recruitment pattern shows that there are two peak recruitment periods, one in May and the other in September for the raw data, accounting for 13.5% and 17.5% respectively (Fig. 7). After correcting for gear selectivity, re-analysis of recruitment still showed two peaks, a minor one in

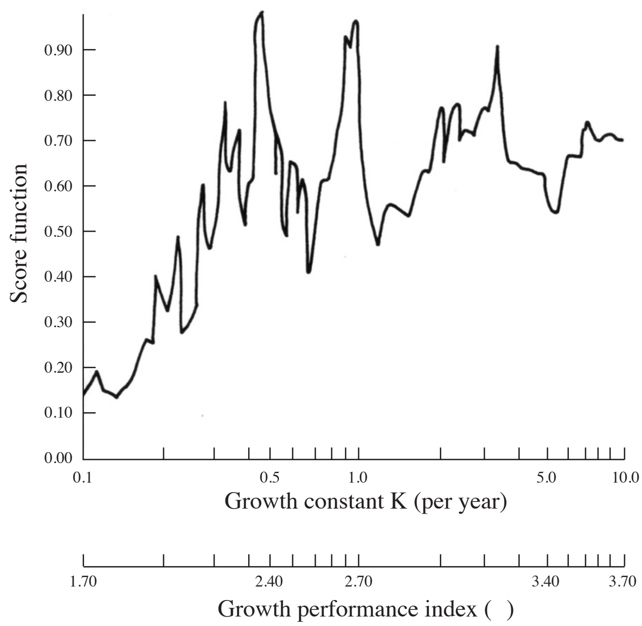

Figure 2. - K-scan routine for determining the best growth curvature giving the best values of asymptotic length with growth performance indices for the combinations given on secondary x-axis. *[Routine de K-scan pour déterminer la courbe de croissance donnant les meilleures valeurs de la longueur asymptotique avec les indices de performance de croissance pour les combinaisons sur l'axe secondaire des x.]*

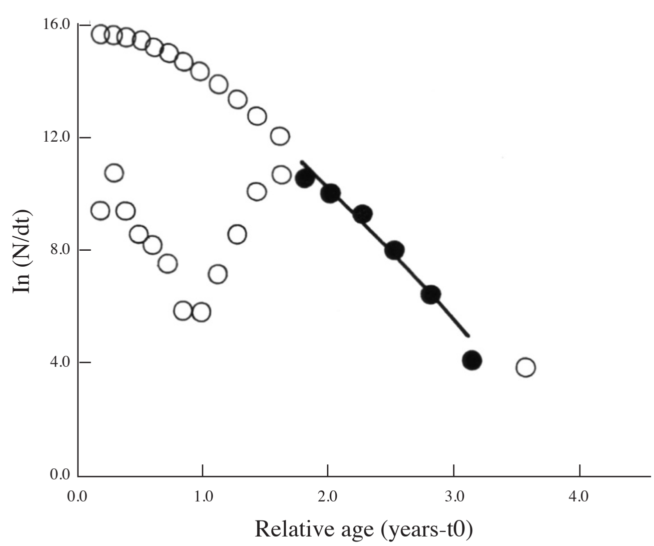

Figure 4. - Length-converted catch curve for *Liza klunzingeri*, showing extrapolation of hadra trap gear selection giving an estimate of 4.27 yr^{-1} total mortality coefficient; Z = 4.61; M (at 24.0°C) = 1.06; F = 3.56; E = 0.77. *[Courbe de capture convertie en longueur pour* Liza klunzingeri, *montrant l'extrapolation de la sélectivité de l'engin, donnant une estimation du coefficient de mortalité totale de 4,27 an*$^{-1}$*.]*

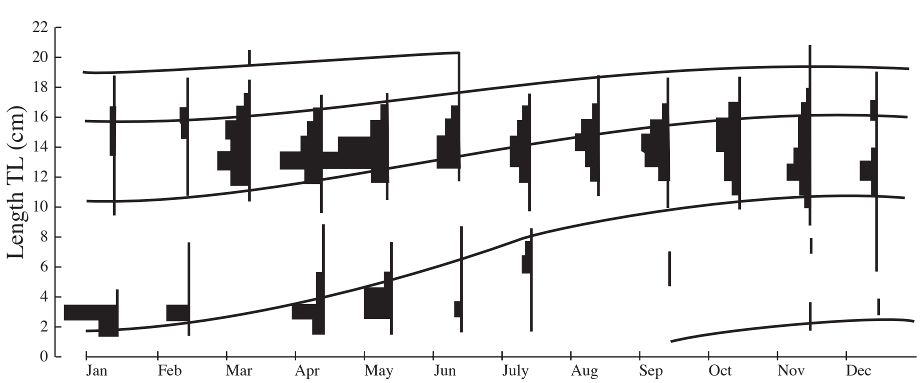

Figure 3. - Seasonally oscillating growth curve for *Liza klunzingeri* from the Kuwait Bay. *[Courbe de croissance oscillante saisonnière pour* Liza klunzingeri *de la baie du Koweit.]*

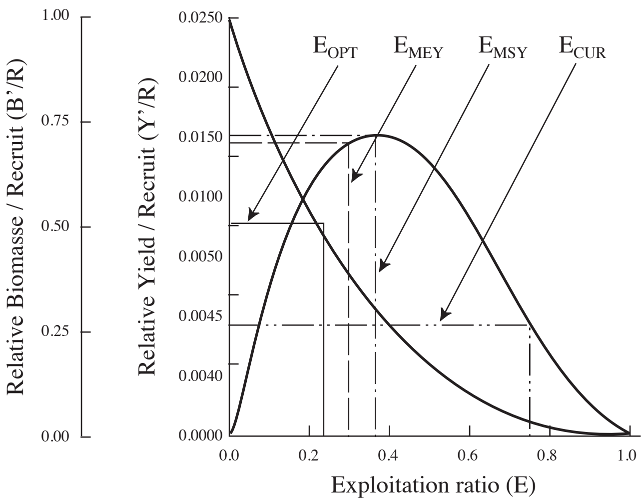

Figure 5. - Beverton & Holt's relative yield-per-recruit and average biomass per recruit models, showing levels of yield indices: E_{OPT} - optimum yield, E_{MEY} - maximum economic yield, E_{MSY} - maximum sustainable yield and E_{CUR} - current level of exploitation for *Liza klunzingeri* in Kuwait Bay. *[Modèle de Beverton & Holt pour le rendement relatif par recrutement et la biomasse moyenne, montrant le niveau des indices de recrutement : E_{OPT} - rendement optimal, E_{MEY} - rendement économique maximal, E_{MSY} - rendement soutenu maximal et E_{CUR} - niveau actuel d'exploitation pour* Liza klunzingeri *dans la baie du Koweit.]*

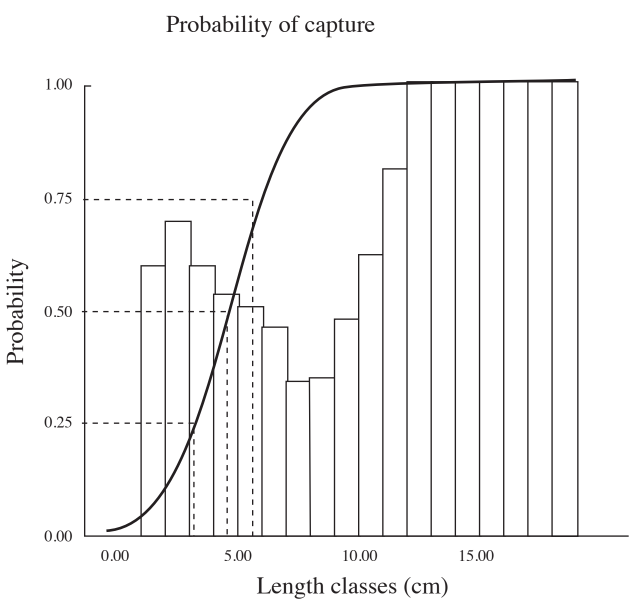

Figure 6. - Logistic selection curve showing 25%, 50% and 75% selection length (cm TL) of *Liza klunzingeri* (broken lines) from the Kuwait Bay. *[Courbe de sélection logistique montrant 25, 50 et 75% de la longueur de sélection (cm TL) de* Liza klunzingeri *(tirets) de la baie du Koweit.]*

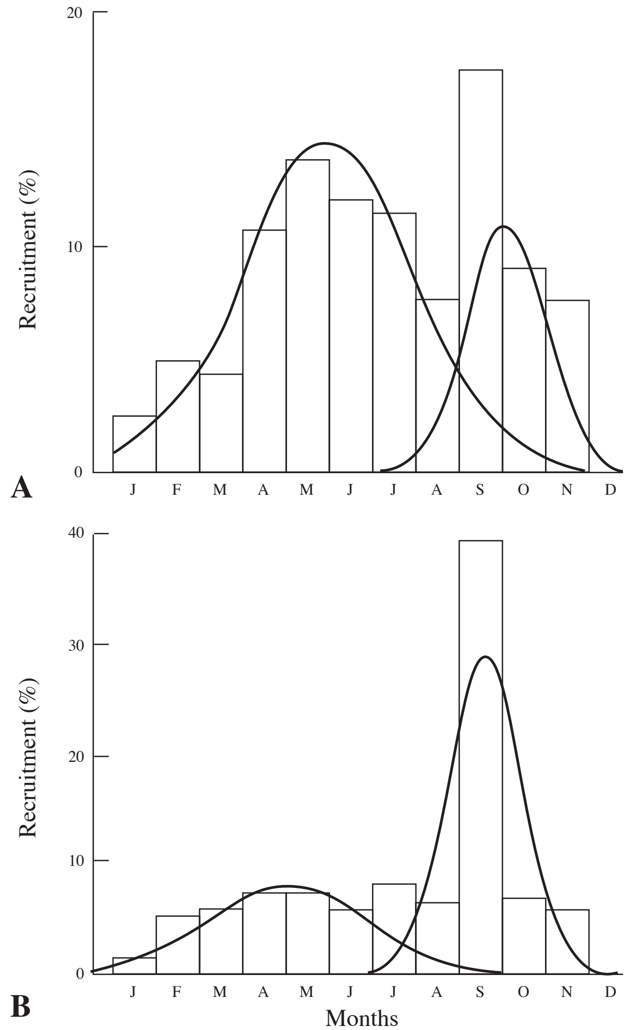

Figure 7. - Estimated percentage recruitment of *Liza klunzingeri* in the Kuwait Bay before (**A**) and after (**B**) correction for hadra gear selectivity. *[Estimation du pourcentage de recrutement de* Liza klunzingeri *dans la baie du Koweit avant (**A**) et après (**B**) correction de la sélectivité de l'engin.]*

April/May, accounting for 8.22%, and a major peak in September, accounting for 37.8% of the total annual recruitment.

DISCUSSION

Growth parameters are generally difficult to estimate from length-frequency distributions when there are no distinct breeding seasons and the distribution does not show any modes. For the case of *L. klunzingeri*, it was possible to attempt growth studies since there were distinctly two cohorts in most of the time-series data (Fig. 3). There is strong evidence that *L. klunzingeri* does not grow much in winter due to the decreased ambient temperature and/or spawning which, in the species, takes place in winter (Al-Khatib 1986; Abou-Seedo and Al-Khatib, 1995; Abou-Seedo and Dadzie, 2004). It is, therefore, justified to use 0.95 (15th December) as a winter point. The use of 0.95 as oscillation amplitude was, however, based on various iterations and

curve fitting on either the original or restructured length-frequency data. The K-scan technique and response surface analysis results were also consistent for the species.

Liza klunzingeri is native to the Arabian Sea, Indian Ocean, Gulf of Oman and Persian Gulf (Randall, 1995). It is therefore a shared marine fish stock. Unfortunately, there is no published data on growth of *L. klunzingeri* locally or regionally, and limited reports are available on closely-related species (Morgan, 1985; Al-Husaini *et al.*, 2001; Al-Husaini, 2002). In the present study, an asymptotic length of 24.8 cm TL and a growth curvature of 0.46 yr^{-1} were determined for *L. klunzingeri*. Al-Husaini *et al.* (2001) reported an asymptotic length of 62.16 cm TL and a growth curvature of 0.27 yr^{-1} for *Pomadasys kaakan* in the same region. These growth parameters give a growth performance index of 3.004 for the latter, as compared to 2.452 for *L. klunzingeri*. In comparison with *Pampus argenteus*, with an asymptotic length of 32.5 and growth curvature of 0.50 yr^{-1} (Morgan, 1985), the growth performance is 2.72. This value still gives *L. klunzingeri* a poor rating as compared to silver pomfret, expected to attain a relatively smaller size at this growth rate. For the silver pomfret to have a similar performance with *L. klunzingeri*, it has to grow at a K value of about 0.27 yr^{-1}. There is thus a clear indication of poor growth of *L. klunzingeri* in Kuwaiti waters. This poor growth performance is probably attributed to the harsh and unstable estuarine conditions characteristics of the Kuwait Bay (Abou-Seedo and Dadzie, 2004). We also draw comparison based on our own experiences with similar data in other regions. For example, two cohorts of *L. klunzingeri*, observed in the present study, is in conformity with findings reported for *Rastrineobola argentea* (Manyala, 1993) and *Limnothrissa miodon* (Mulimbwa and Mannini, 1990). However, identification of different cohorts using length-frequency distribution still remains a challenge in the use of this technique in growth studies.

In dealing with mortality rates, it is usually important to correct for gear selectivity since more of the larger specimens are removed by fishing and less of the smaller ones appear in catches. It is also argued that fishes grow at a slower rate as they become larger and the time taken to grow through a given length-class increases with size or age (Sparre and Venema, 1992). It was thus necessary to correct for gear selectivity for final determination of total mortality from the length-converted catch-curve analysis. It was revealed that uncorrected samples gave higher total mortality coefficient (4.61 yr^{-1}) as compared to corrected samples (4.27 yr^{-1}). This level of mortality is quite high as compared to other studies in the region, of 1.499 to 1.618 (Morgan, 1985) and 0.24 to 0.36 (Al-Husaini *et al.*, 2001). Morgan (1985) has pointed out that some of the estimates may be biased downwards. In these studies, change in mortality with size was not considered and values as low as 0.46 were obtained. We therefore observe that downward bias in the estimate can be introduced through sampling of fish that are not fully recruited but there is also a danger of upward bias by not sampling the lower length classes when they are already fully recruited. These limitations are better addressed by individual sampling programs through quality control.

The high total mortality coefficient estimated in this study indicates that this small-sized species, which grows to a maximum of only 20 cm (Carpenter *et al.*, 1997), is currently over-exploited. Slightly lower values up to 3.6 yr^{-1} have been obtained in the tropics for small-sized species (Manyala *et al.*, 1995). High total mortality coefficients, however, seem to be a feature of small-sized fishes (Marshall, 1993).

The current exploitation rate of 0.753 for *L. klunzingeri*, derived from the analysis of mortality rates, is already above the maximum, optimum and economic yield indices. Comparison of this value with 0.444 for *P. kaakan* (Al-Husaini *et al.*, 2001) and 0.639 for *P. argenteus* (Morgan, 1985), leads to the strong indication that *L. klunzingeri* is over-exploited in Kuwaiti waters.

The impact of population parameters on the biomass and yield is best reflected in the Beverton and Holt's Yield Per Recruit Model (Beverton and Holt, 1966). At the current mortality rates, the observed exploitation rate of 0.753 is more than twice the Maximum Sustainable Yield (MSY). This indicates an over-exploitation of the *L. klunzingeri* in Kuwait Bay. Gulland (1984) discussed the use of this model with respect to target fisheries. If fisheries managers are looking at a given stock in terms of national economy, whole national fishery or nutritional demands, then achieving Maximum Economic Yield (MEY) is likely to result in a higher total food supply than MSY. The estimated MEY (0.305) for this study is less than half the observed MSY (0.753), still painting a bleak picture for *L. klunzingeri* in Kuwait Bay.

Results obtained from the logistic gear selection model suggest an L50% of 4.8 cm TL, a condition which may have serious consequences for the management of *L. klunzingeri* in Kuwaiti waters. It is critical to impose a ban not only during the critical time in the life history of *L. klunzingeri*, but also to consider the impact of the fishing gear. Given that most of the intertidal species in the Kuwait Bay are spring/summer spawners (Wright *et al.*, 1996; Dadzie *et al.*, 1998, 2000a), any ban imposed on the species as a regulatory measure should take into consideration its impact on the multi-species fishery in the Kuwaiti waters. It is generally believed that short-lived species like *L. klunzingeri* breed before they reach half of their life span. However, when the 50% selection length is only 4.8 cm TL for a fish like *L. klunzingeri* which reaches only 20 cm TL, this is a direct evidence of recruitment-overfishing which cannot be overlooked. Normally, many fishes start to breed at half their life span, indicating that individuals of *L. klunzingeri* are recruited before they mature.

Since *L. klunzingeri* is a winter spawner, it seems, from the results of this study, that the juveniles will have a lag in time before becoming available to the fishery. From the recruitment pattern analysis, there seems to be a minor recruitment in May, but the juveniles recruit into the fisheries mainly in September. Thus, the period between the major recruitment and the onset of spawning (Abou-Seedo and Dadzie, 2004) is only two months. The major recruitment, in September, is logical, given that the species spawns once a year in Kuwaiti waters, and, according to Abou-Seedo and Dadzie (2004), a resurgence of gametogenesis begins in September, resulting in spawning from November. It is also important to note that the results generated by recruitment analysis are based on two assumptions that are rarely met in reality. First, all fish in the sample grow, as described, by a single set of growth parameters and secondly, at least one month out of twelve, always has zero recruitment. Using restructured data reduces the temporal spread and thus probably better reflects the actual seasonality of recruitment.

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